



Estimating CH₄ and N₂O Emissions Using Tower Measurements in California

**Seongeun Jeong¹, Chuanfeng Zhao², Ying-Kuang Hsu³, Arlyn E. Andrews⁴,
Laura Bianco^{4,5}, Patrick Vaca³, Edward Dlugokencky⁴, James M. Wilczak⁴,
Ken Reichl¹, Marc L. Fischer¹**

¹Environmental Energy Technology Division, Lawrence Berkeley National Lab, Berkeley, CA

²Atmospheric, Earth and Energy Division, Lawrence Livermore National Lab, Livermore, CA

³California Air Resources Board, 1001 "I" Street, Sacramento, CA

⁴Earth System Research Laboratory, NOAA, Boulder, CO

⁵Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO

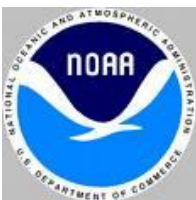
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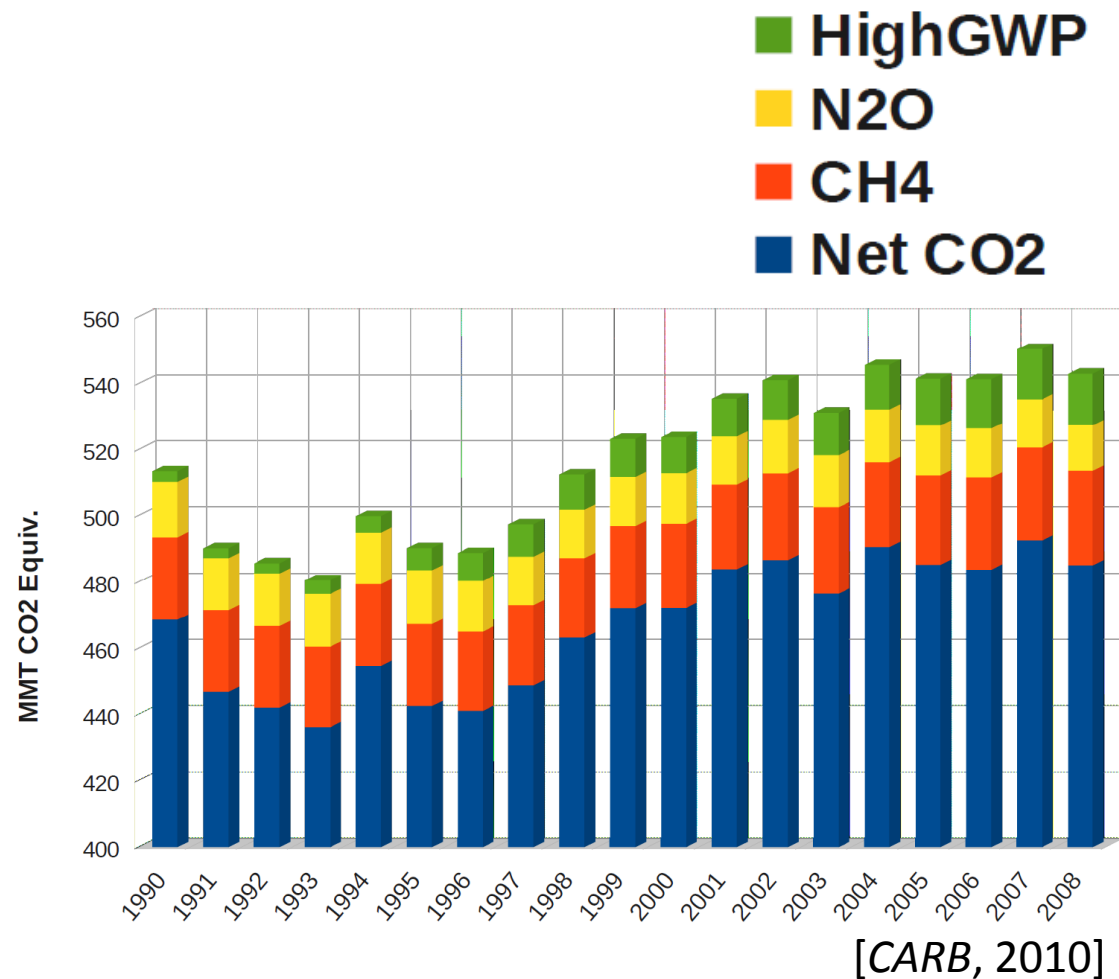


Outline

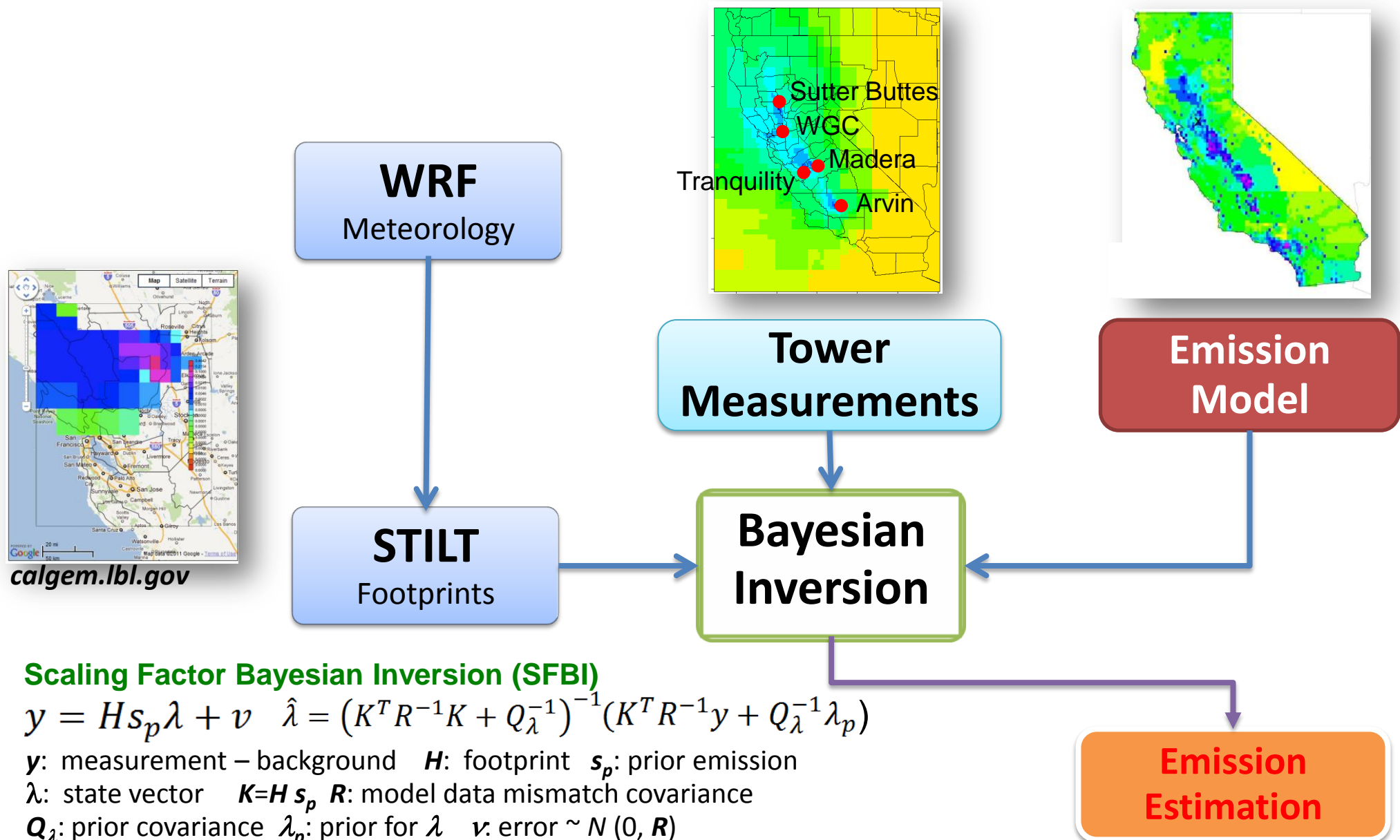
- Introduction
- Approach
- Results of non-CO₂ GHG emissions for California
- Implications for California

Introduction

- California is the first state in US to legislate GHG controls
 - AB-32: Return to 1990 levels by 2020
- Total non-CO₂ GHG emissions ~10% of CA total inventory
 - Uncertainties in inventories are large
 - Industrial and biological sources are not readily metered
- Atmospheric inverse method provides independent check

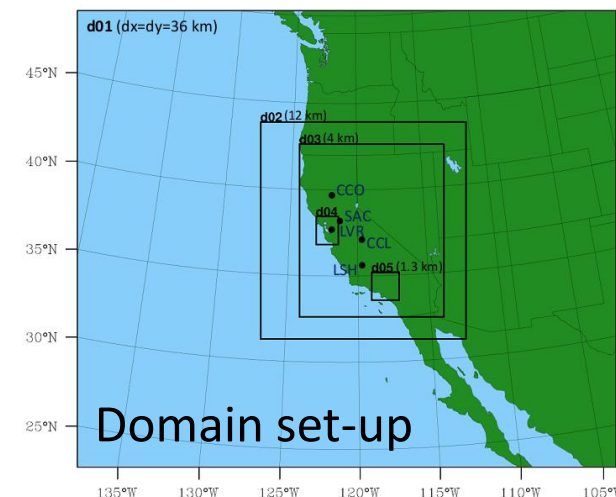


Approach

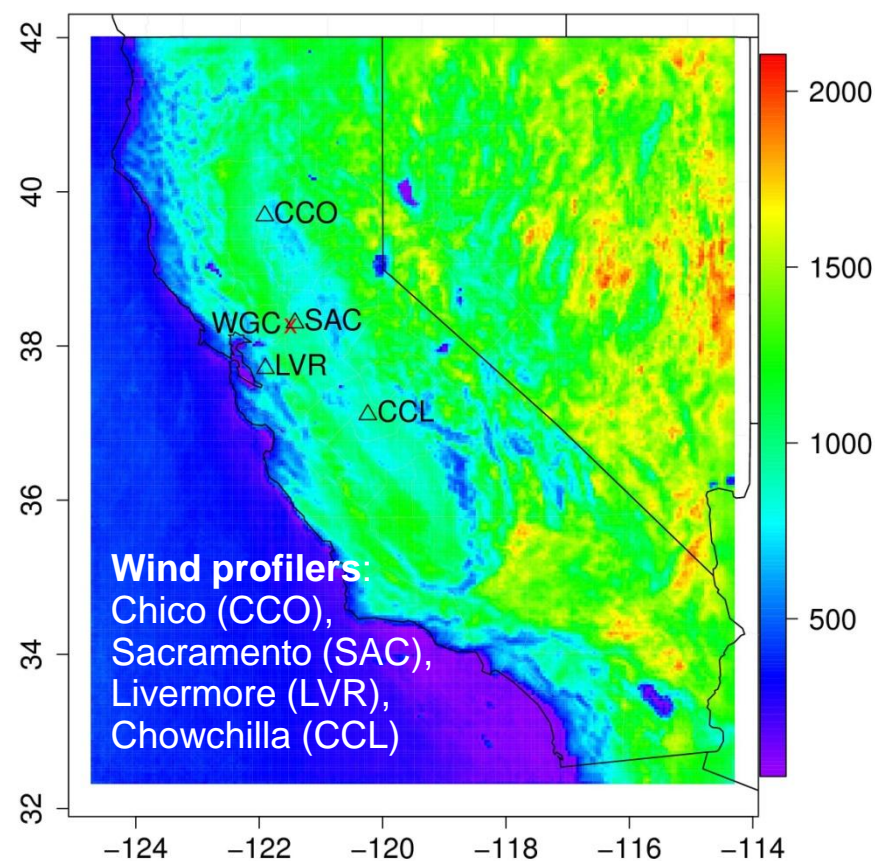


Meteorological Model for CA

- Weather Research Forecast (WRF) Model
 - North American Regional Reanalysis (NARR) boundary and initial conditions
 - 6-hour spin-up [Zhao *et al.*, 2009]
 - Two-way nesting WRF running with four nest levels (five domains)
 - 5-layer thermal diffusion land surface scheme (LSM) during summer
 - NOAH LSM during other seasons
 - MYJ PBL scheme



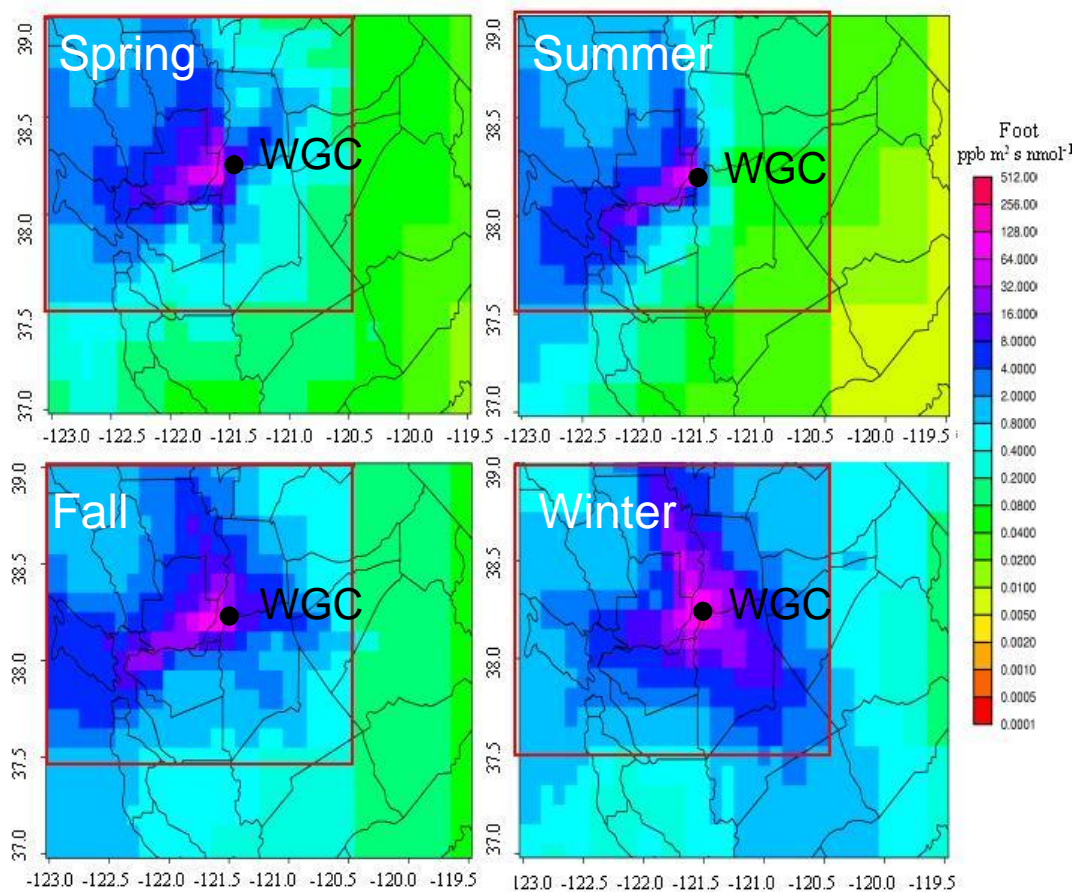
Monthly mean midday PBL, June 2008



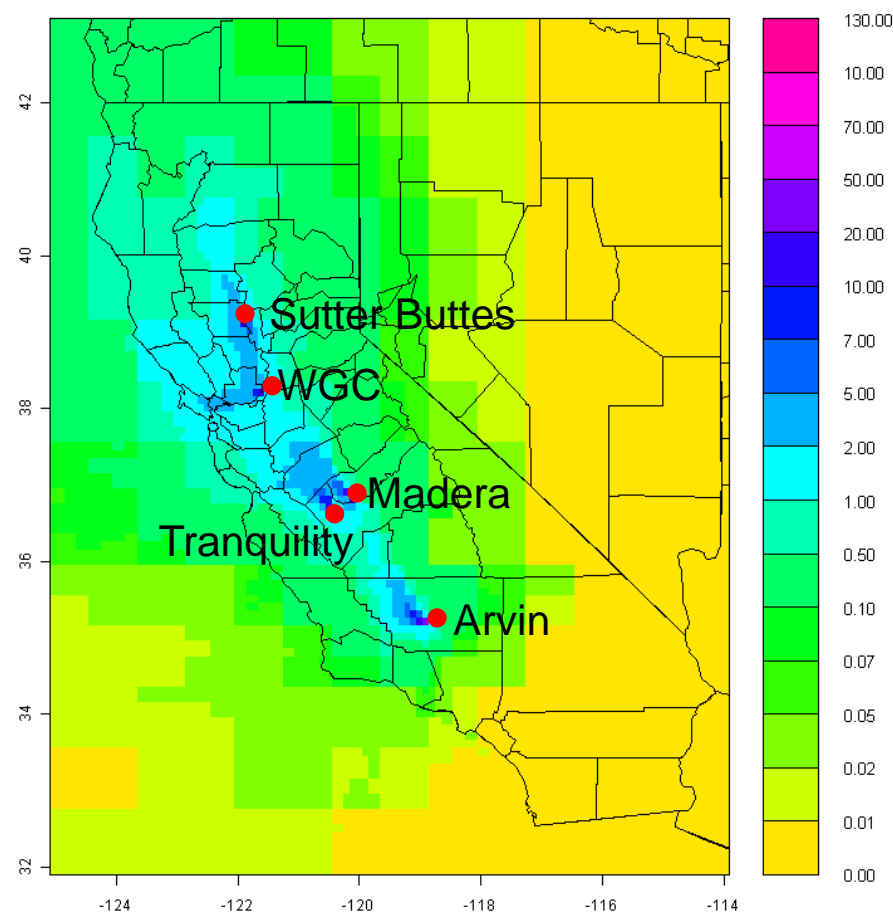
STILT Footprint Simulations

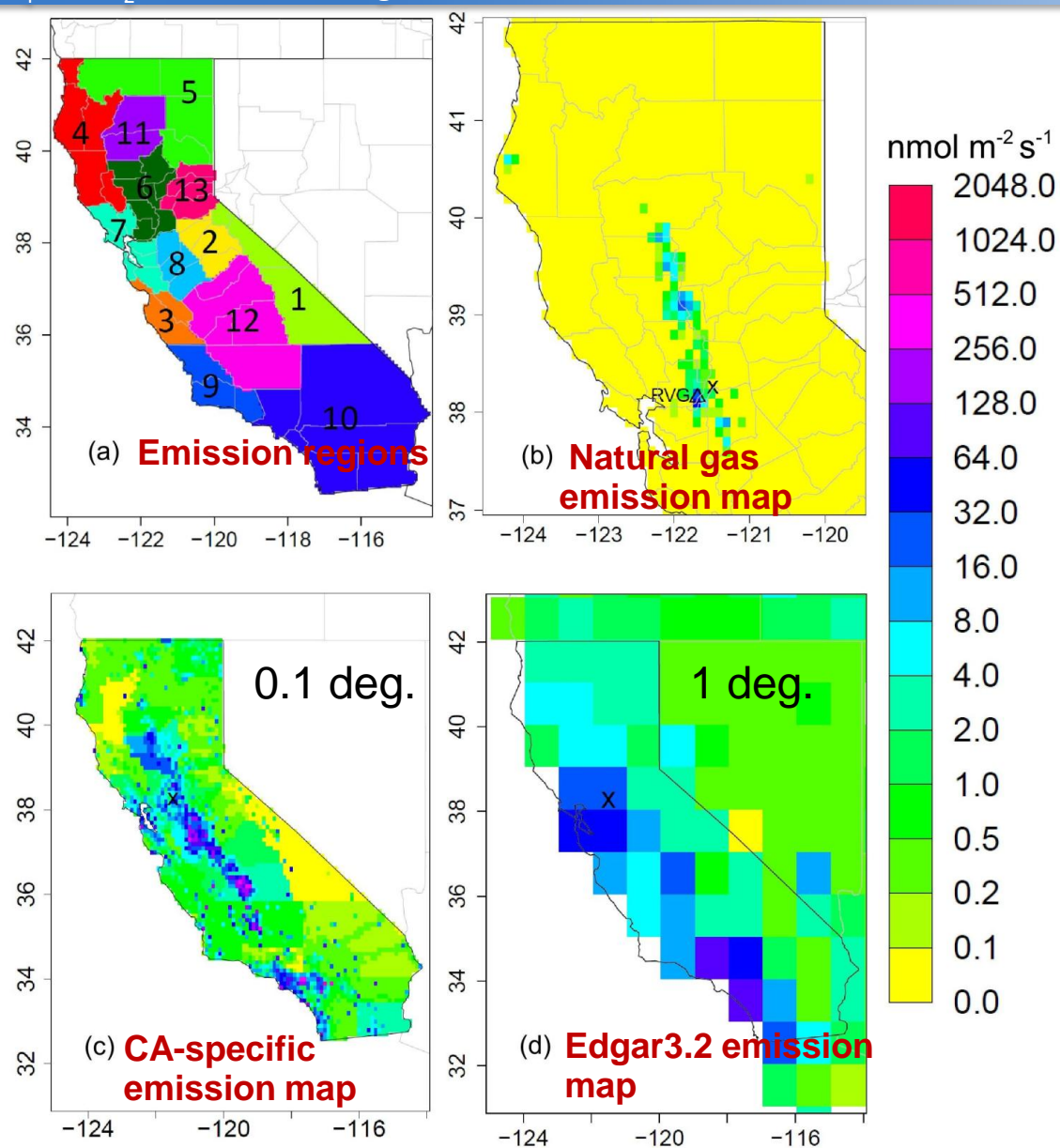
- STILT footprints relate surface emissions to predicted signals at towers
- Footprints vary with season, capturing emissions from different regions
- Multiple towers improve sensitivity over a larger area

Seasonal Mean Midday Footprints, WGC
(Dec 2007 – Nov 2008)



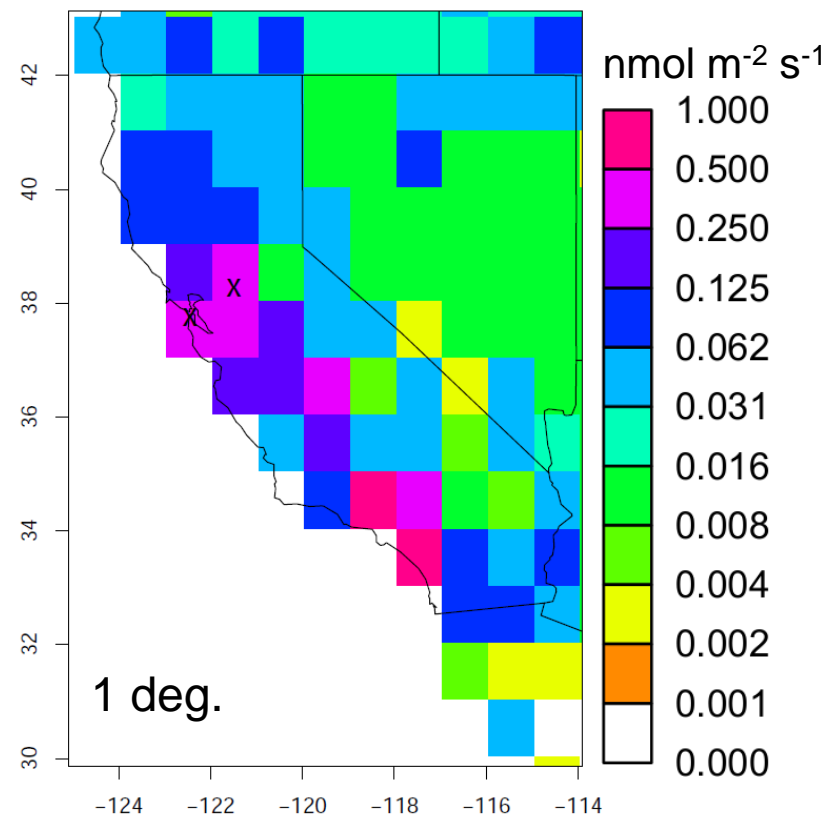
Mean Midday Footprints from Multiple
Towers (May – June 2011)



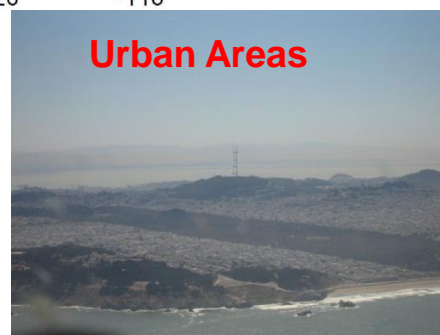


Prior Emissions

Edgar3.2 N₂O *a priori* Emission Map

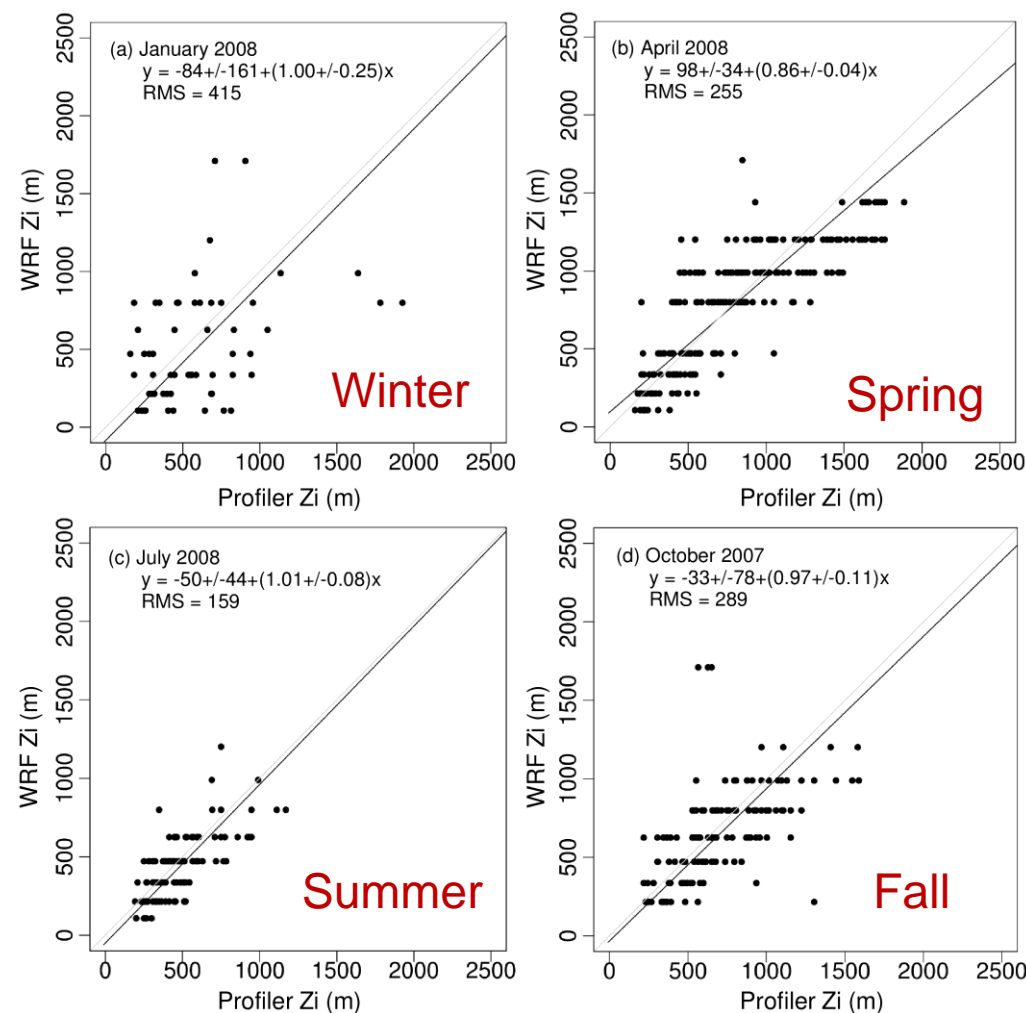


CH₄ *a priori* Emission Maps



Error Analysis for Inversion

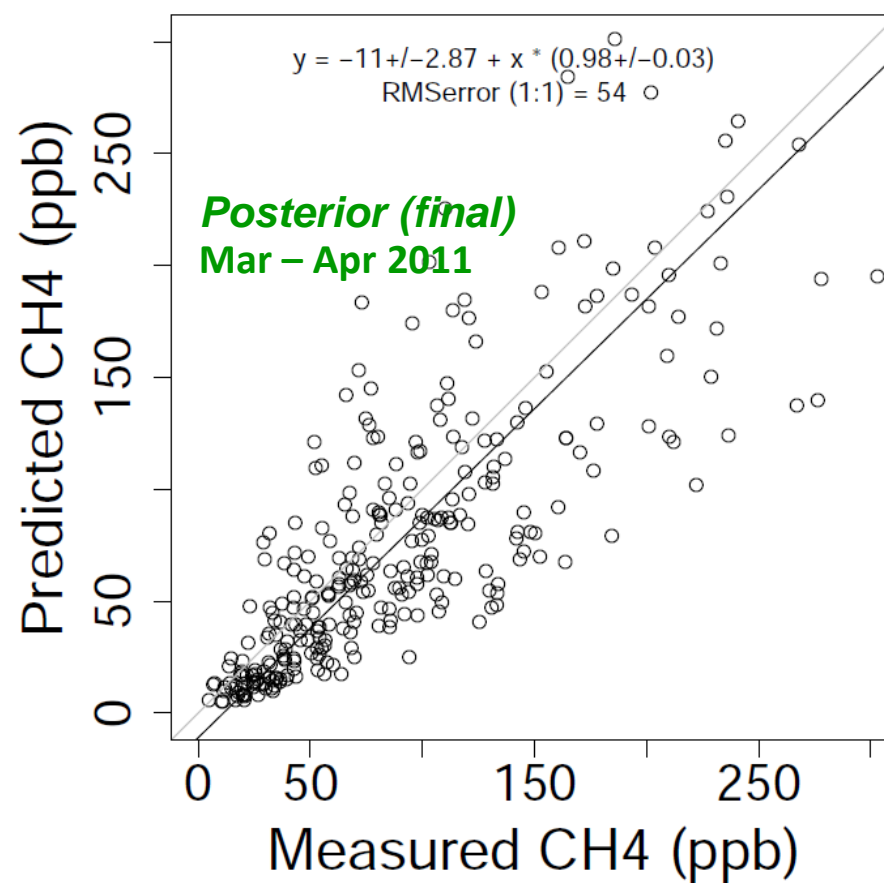
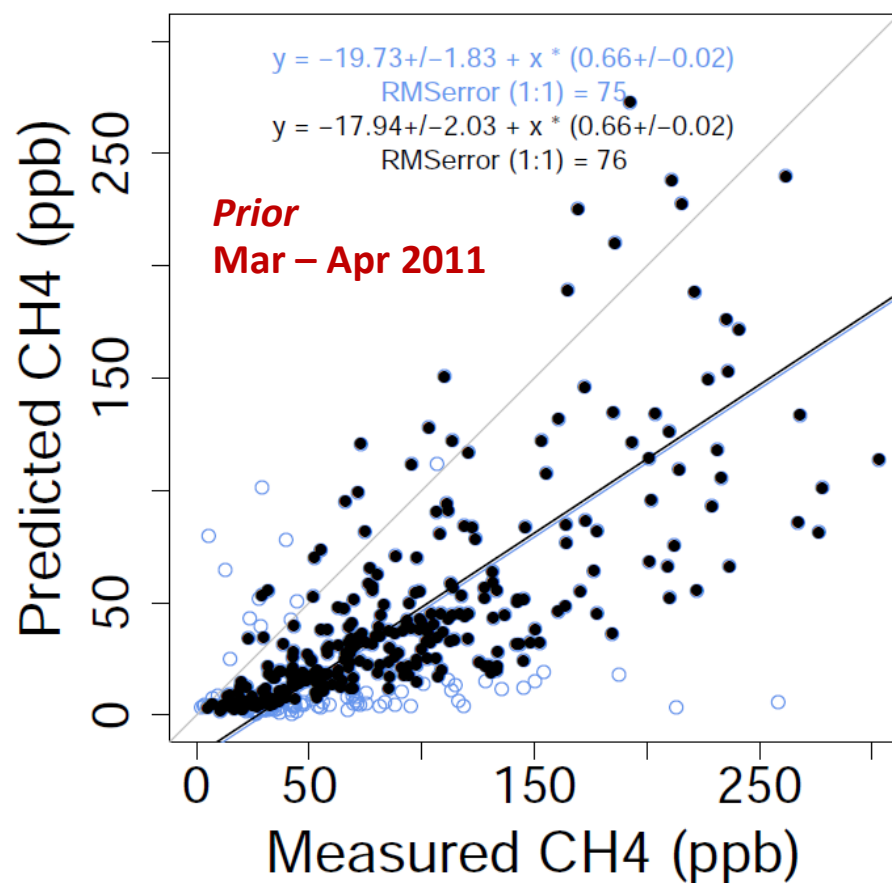
- Quantify error sources
- Propagate errors through modeling system to provide quantitative uncertainties
 - Boundary layer ~ 20 - 45 %
 - Wind Velocity ~ 10%
 - Background ~ 10 - 60 %
 - Aggregation ~ 11 %
 - Other ~ 8%
- Quadrature sum ~ 50 - 65% of signal for individual time points



Comparison of predicted and measured boundary layer heights (Z_i), Sacramento

Model Measurement Comparison for CARB-CEC-LBNL-NOAA Network, 2010 – 2011

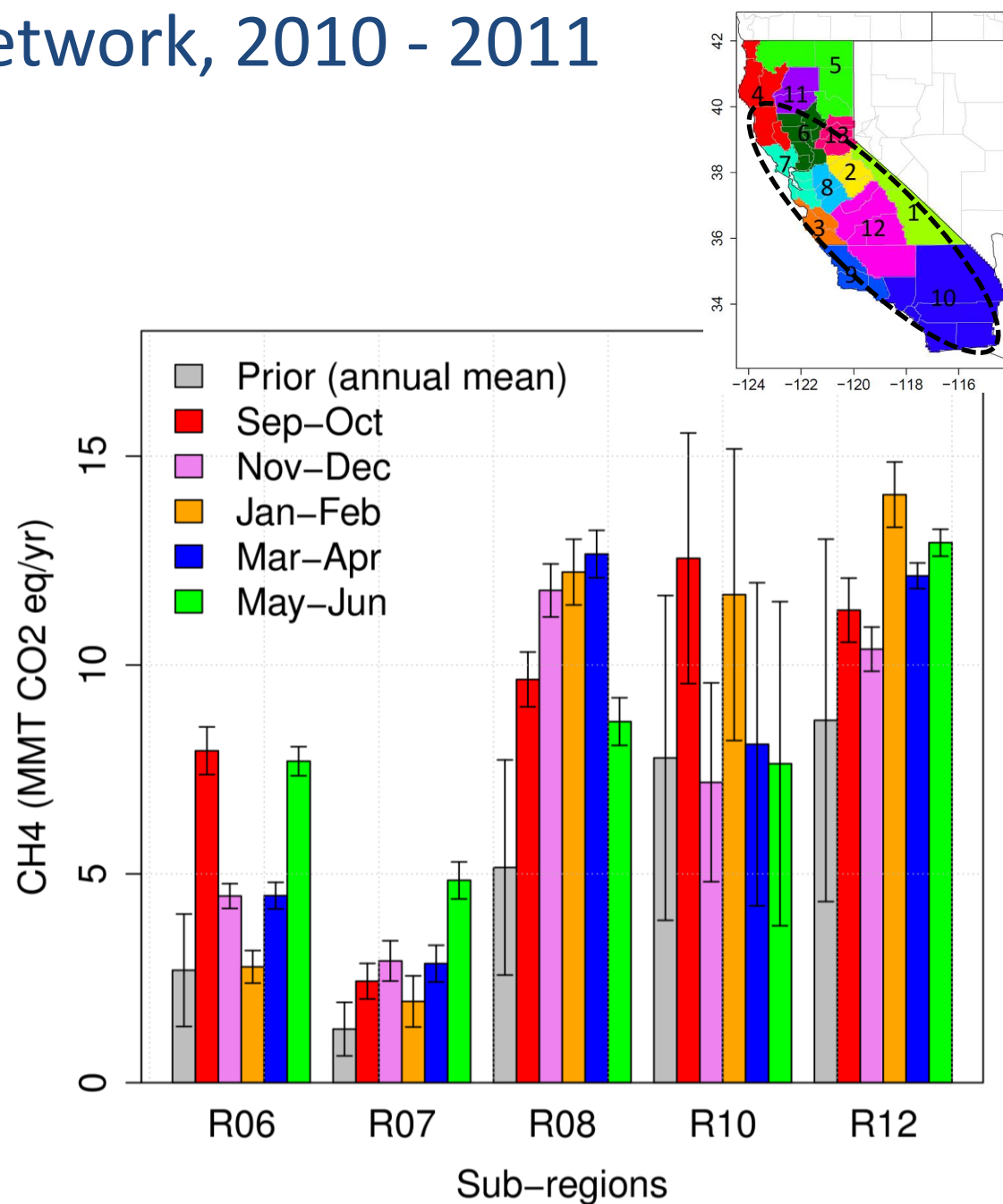
- Predicted signals are typically 55 – 75 % of measurements
- Outliers are removed after initial inversion [*Bergamaschi et al.*, 2005]
- Inverse (50% error in prior) produces posterior predictions consistent with measurements



Bayesian Inverse Emission Estimate

CH₄ Tower Network, 2010 - 2011

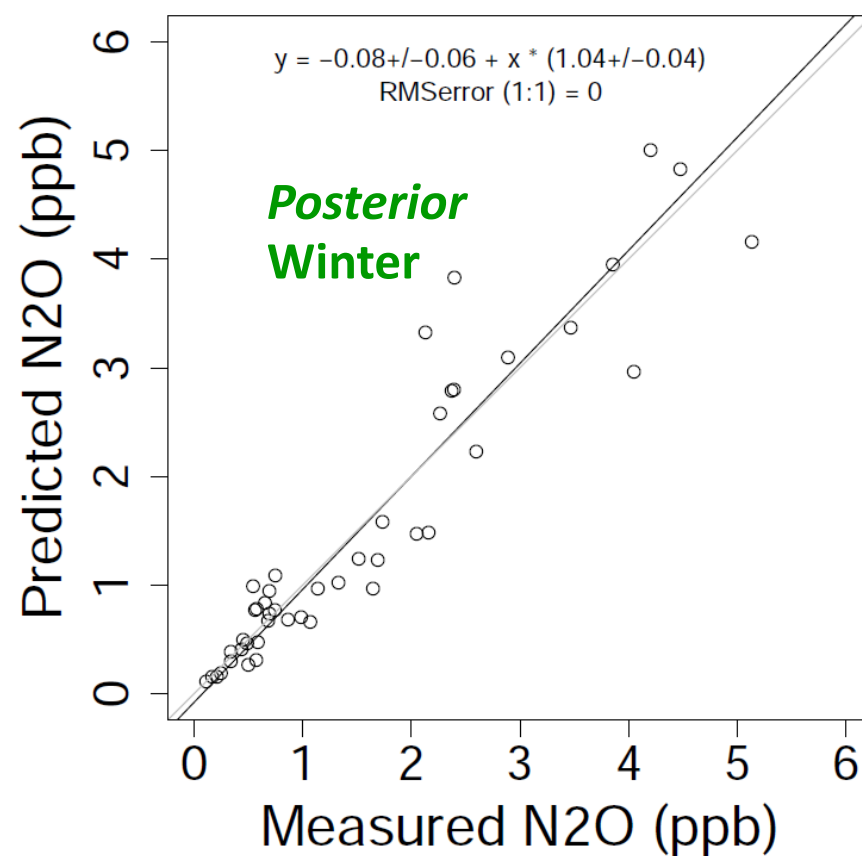
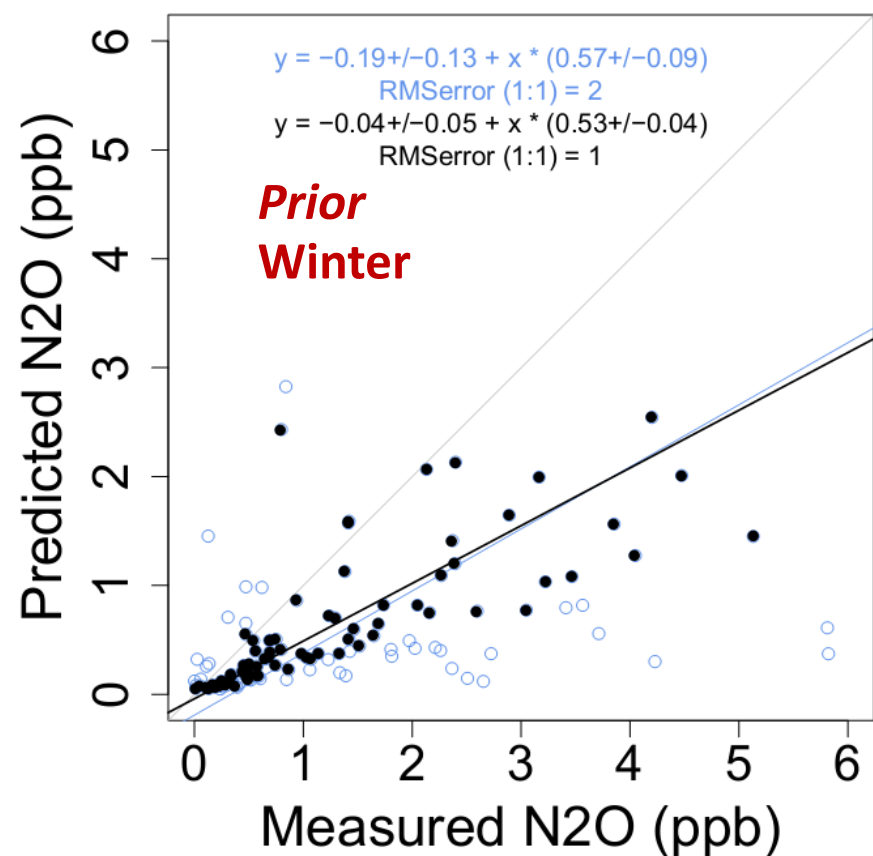
- Tower network constrains \sim 90% of CA CH₄ emissions
- Posterior emissions 1.6+/-0.1 times CARB inventory
- Most significant error reductions obtained in Central Valley
- Additional towers would improve constraint on So Cal air Basin
- Seasonality in some regions indicative of underlying processes (e.g., rice in region 6)



Model Measurement Comparison for N₂O

Walnut Grove, 2008 - 2009

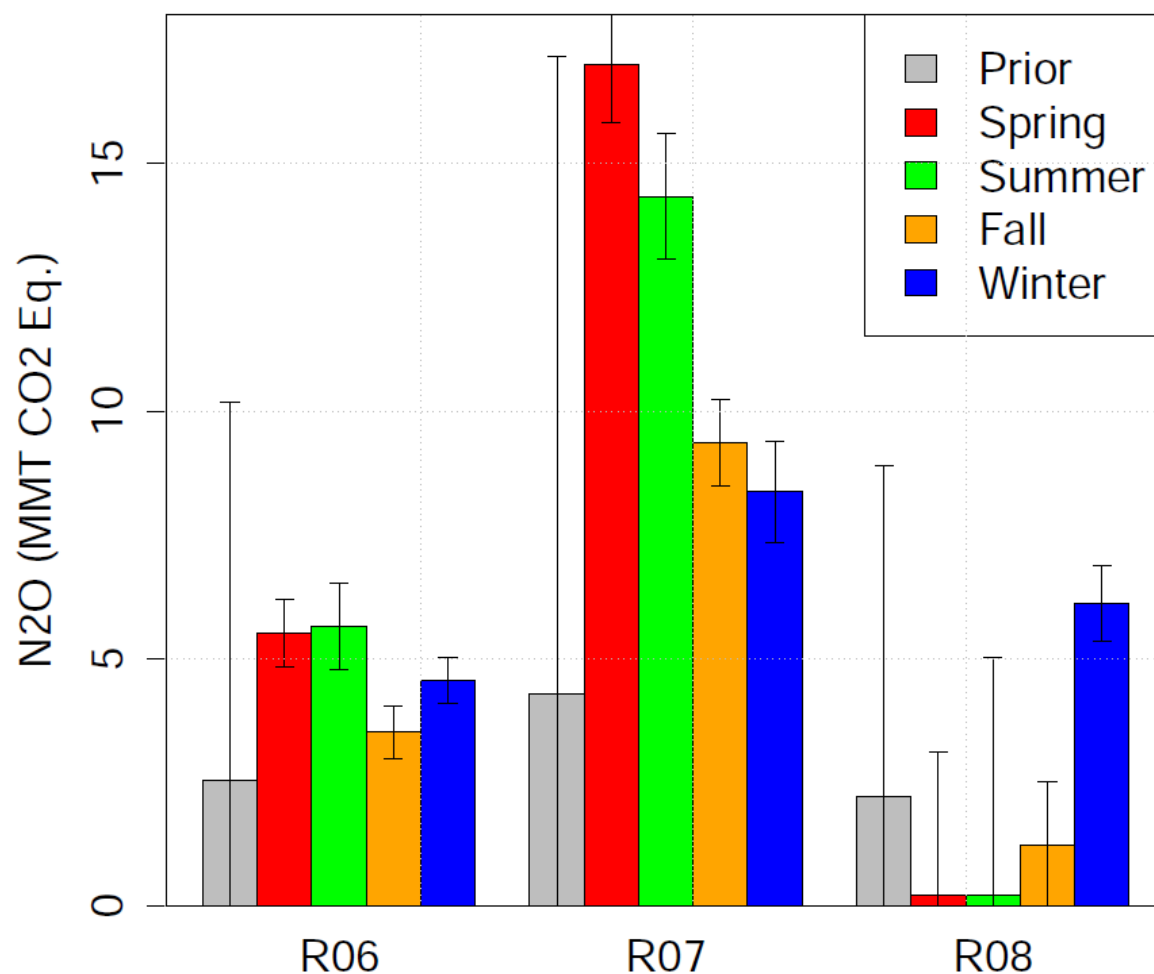
- N₂O emissions estimated by two years of daily N₂O flask measurements and Edgar3.2 emission maps (1 deg. X 1 deg.)
- Predicted signals are typically 20 – 50% of measurements
- Inverse produces posterior predictions consistent with measurements



Bayesian Inverse N₂O Emission Estimate

WGC, 2008 - 2009

- Annual mean posterior N₂O emissions for Regions 6, 7, 8 are 19.0+/- 2.8 MMT CO₂ eq
 - significantly greater than CARB total for CA (~13 MMT CO₂ eq)
 - ~3 times Edgar3.2 emissions
 - ~5 times CARB total for CA if actual spatial distribution follows Edgar



Implication for California Non-CO₂ Emissions

- Posterior CH₄ emissions: 44.8+/-3.6 MMT CO₂ eq. for CA
 - 1.6+/-0.1 times CARB inventory (28 MMT CO₂ eq.)
- Posterior N₂O emissions for Regions 6, 7, 8: 19.0+/-2.8 MMT CO₂ eq.
- If Edgar spatial distribution applies – questionable
 - Total California CH₄ and N₂O emissions constitute ~20% of total CARB GHG emissions (543 MMT CO₂ eq.)
- Additional measurements needed

Thank You!